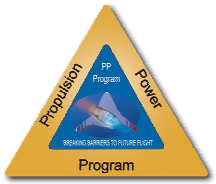
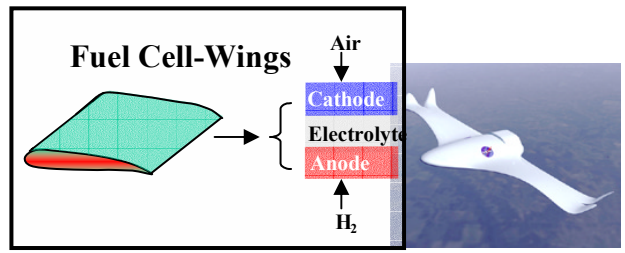
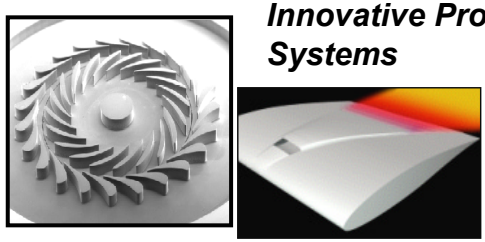


Propulsion & Power

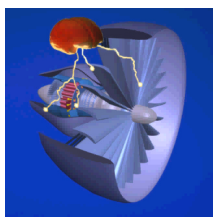
Transport Electric Propulsion

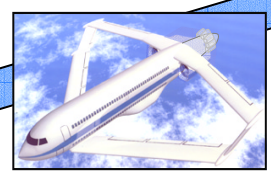


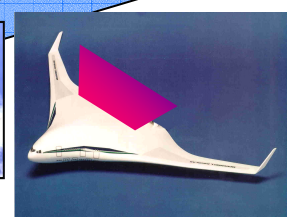
Innovative Propulsion Systems



Intelligent Engine



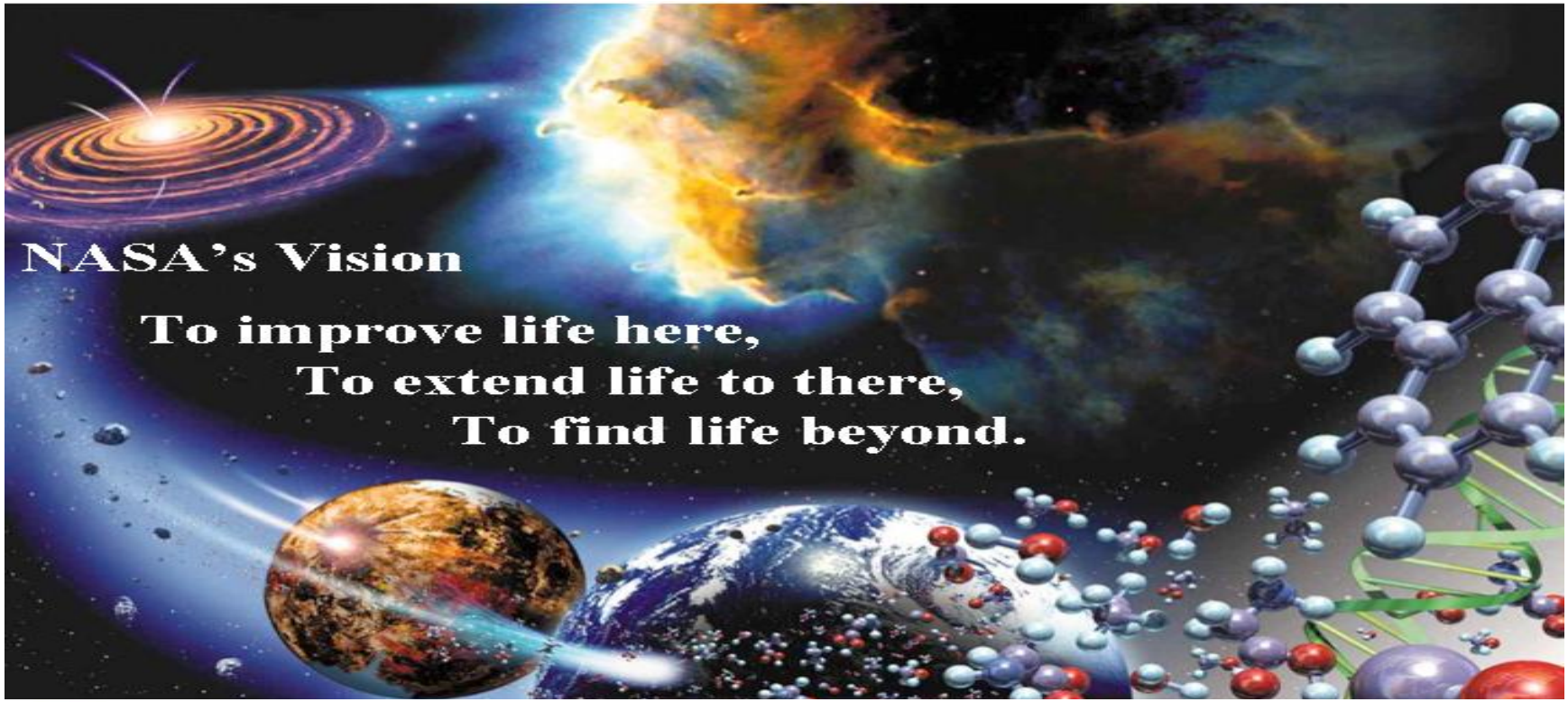




Dr. Gary T. Seng, Program Manager
NASA Glenn Research Center
November 18, 2002

Presentation Outline

- Mission, Programs & Goals
- Current Investment Areas
- Future Directions



The NASA Mission

To understand and protect our home planet
To explore the Universe and search for life
To inspire the next generation of explorers

… as only NASA can.

NASA Enterprises---From Strategic Plan to Programs

Vision

Mission

Agency Goals (10)
What we will achieve

Themes (18)
Our structure to implement the Goals

Objectives (~60)
How we will achieve the Goals

Implementing Strategies
A foundation of sound planning and management practices

Mission-Driven Enterprises & Enabling Capability

- Space Science
- Earth Science
- Bio & Phys Res.
- Aeronautics
- Space Flight
- Education

Agency Themes (4 of 18)

- Aeronautics Technology
- Space Launch Initiatives
- Mission & Science Measurement Technologies
- Commercial Technology

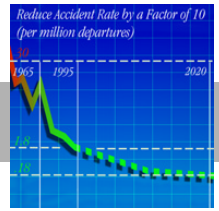
Enterprise Level 1 Programs

- Vehicle Systems
- Airspace Systems
- Aviation Safety & Security

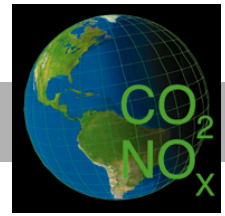
Level 2 Programs

- UEET
- Quiet Aircraft Technology
- TCAT
- Propulsion & Power
- Breakthrough Vehicles
- Flight Research
- Advanced Vehicle Concepts

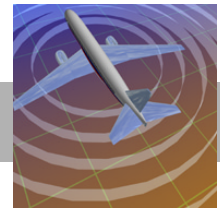
Aeronautics Technology



Increase Safety



Reduce Emissions

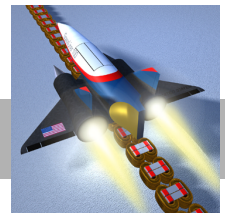


Reduce Noise

Increase Capacity

Increase Mobility

Space Launch Initiative

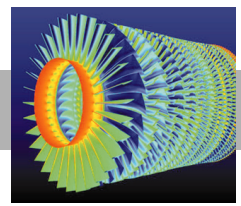


Mission Safety

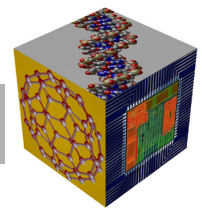
Mission Affordability

Mission Reach

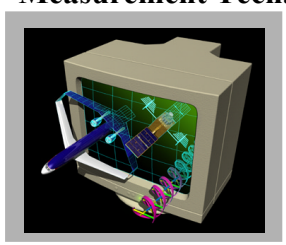
Mission & Science Measurement Tech.



Engineering Innovation

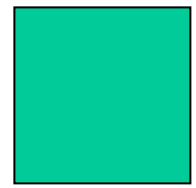


Technology Innovation

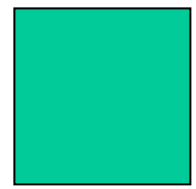


Commercial Technology Partnerships

New Aero Objectives



Protect the Nation

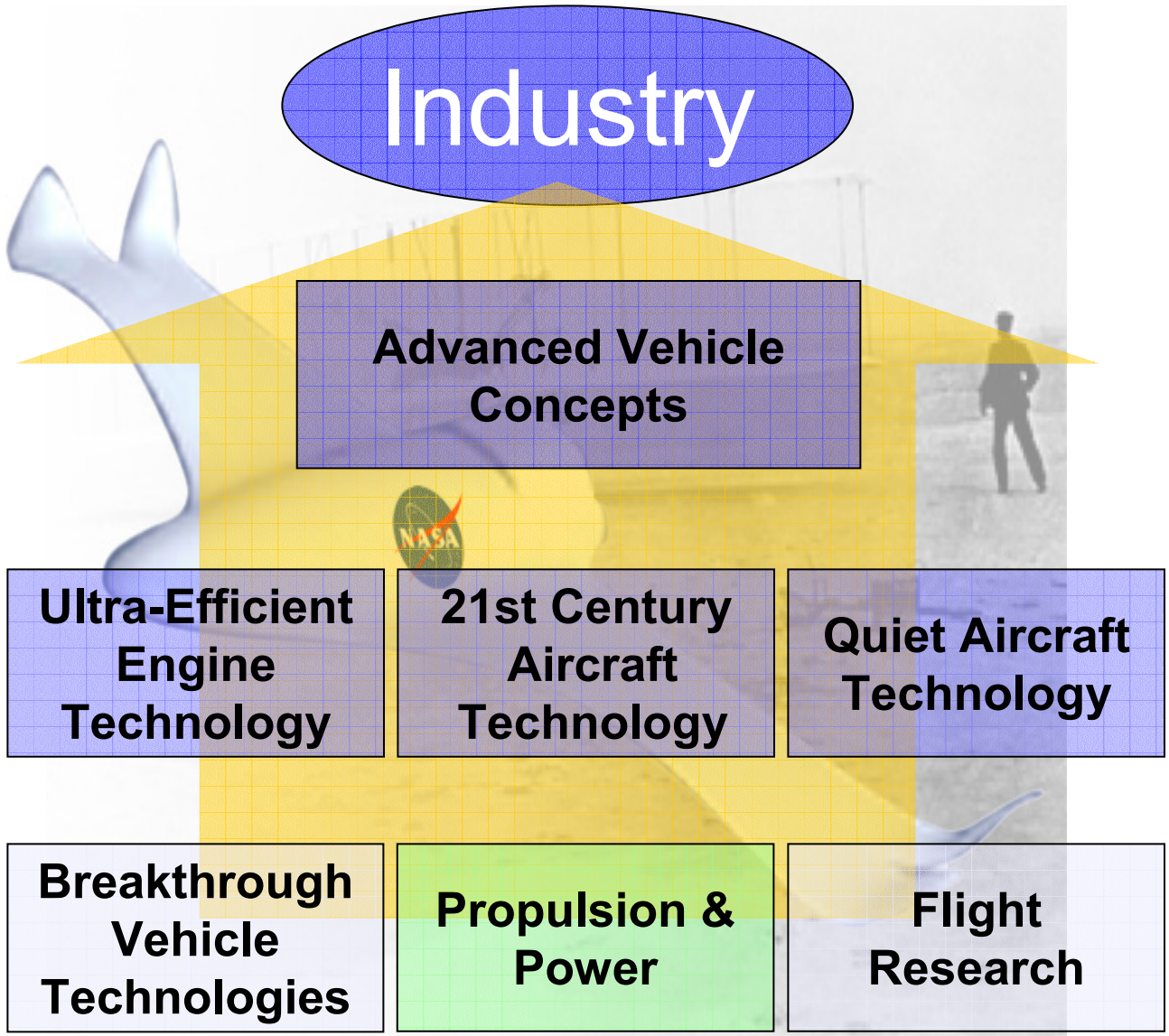


Explore Revolutionary Aero Concepts

Enterprise Objectives

In Progress - Draft

Vehicle Systems



Propulsion & Power Program – Mission Statement

Provides leadership for the development of breakthrough aeronautics technologies to maintain U.S. technological and environmental superiority of propulsion and power systems

PROPULSION & POWER PROGRAM - Investment Areas & Projects

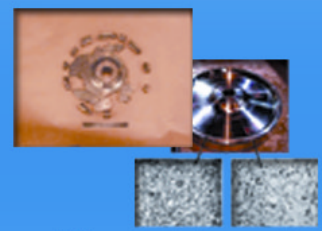
National Aeronautics and Space Administration

Glenn Research Center

Turbine Engine Technologies

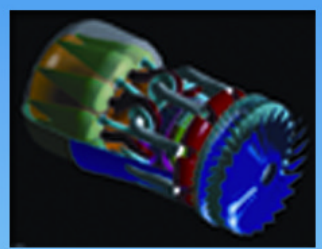
Smart Efficient Components

Oil-Free Turbine Engine Technology



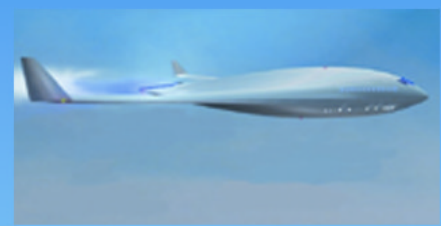
UltraSafe Propulsion

New Propulsion Concepts



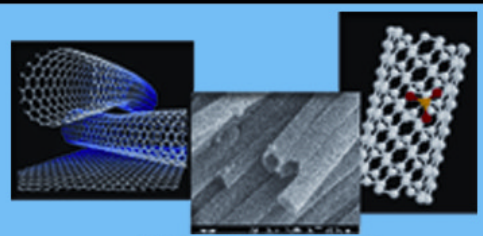
Pulse Detonation Engine Technology

Revolutionary Aeropropulsion Concepts



ZERO CO2 Emission Technologies

Foundation Technologies



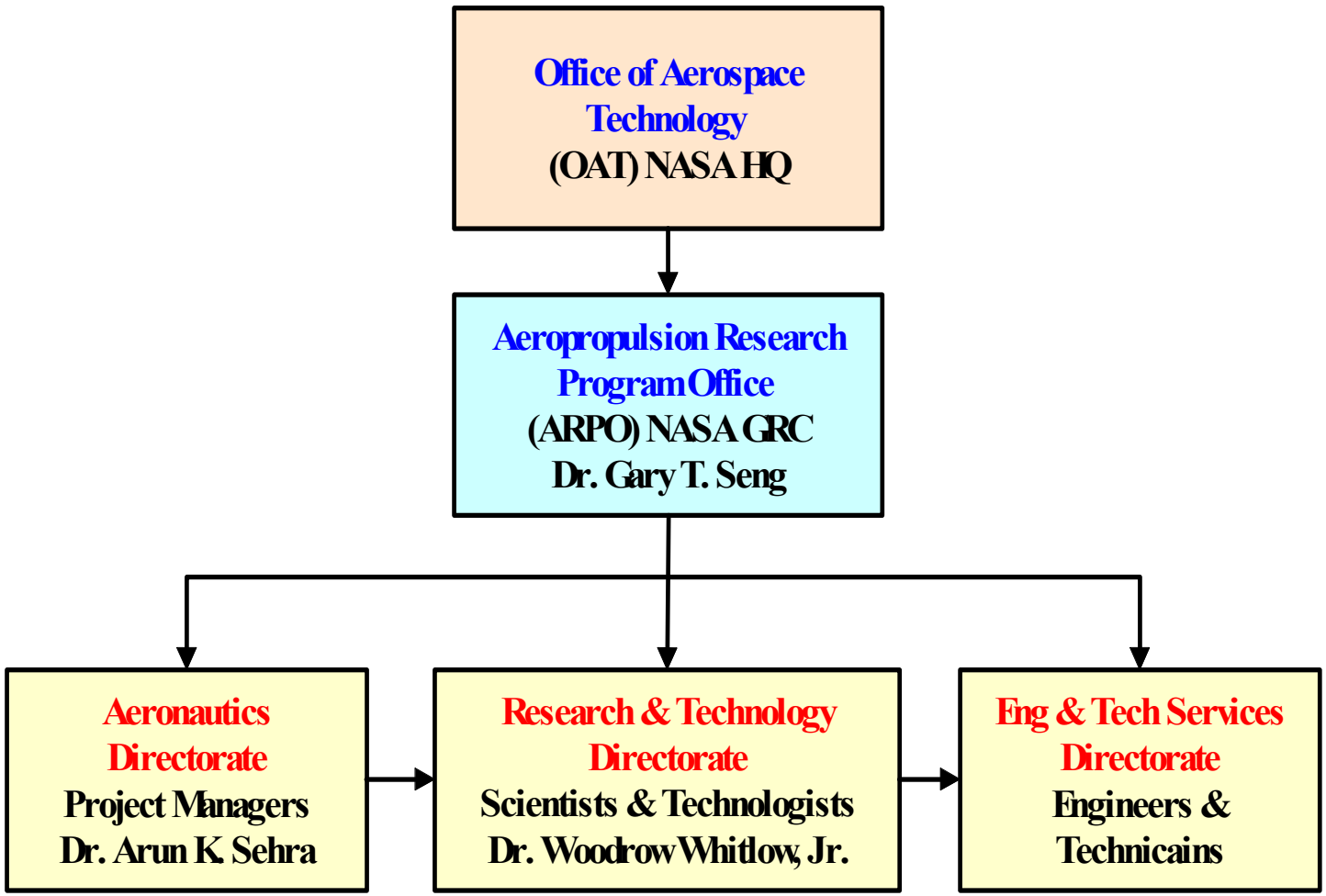
High Temperature Nanotechnology

University Research, Engineering & Technology Institute (URETI)

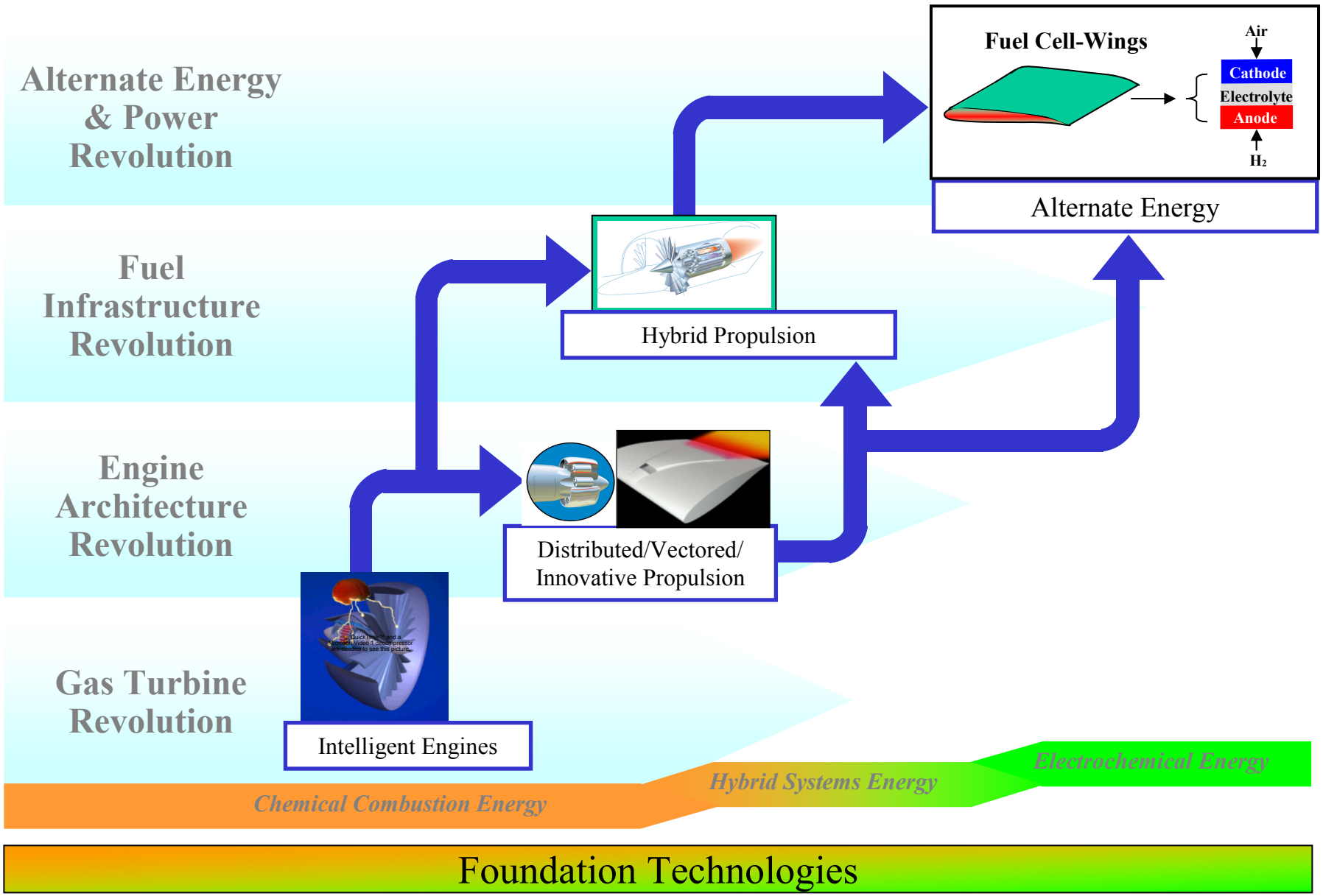
Higher Operating Temperature Propulsion Components

Program Flowdown to Matrix Organization

"How Work Gets Done"



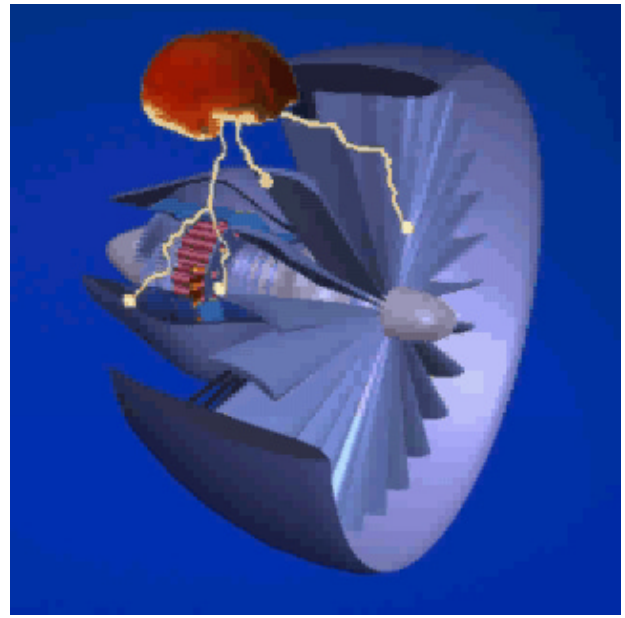
Aeropropulsion – NASA's Future Directions

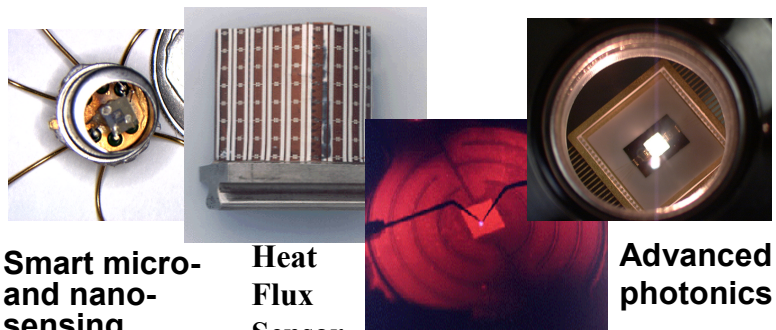


Intelligent Engine Technologies - Ultra-clean, Ultra-Quiet,

Intelligent Engine Attributes & Technologies

Attributes	Technologies
• Sensing	- Embedded micro- and nanosensors
• Thinking	- Coupled simulation and data-feedback health and performance management
• Reacting	- Autonomic engine control strategies



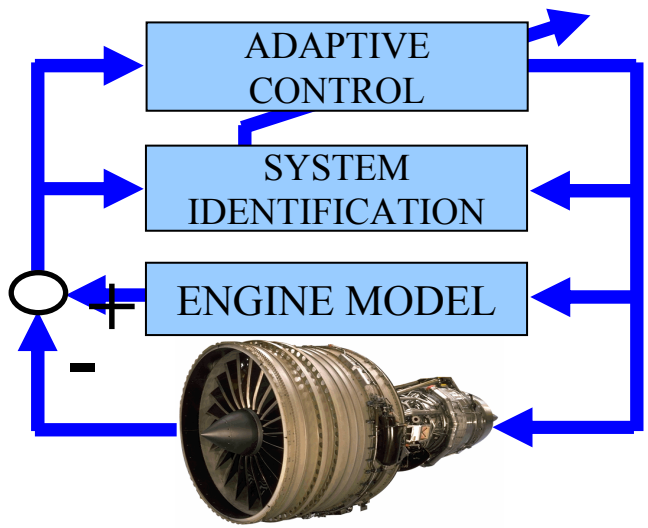


Smart micro- and nano-sensing, computation, and actuation

Heat Flux Sensor

Advanced electronics

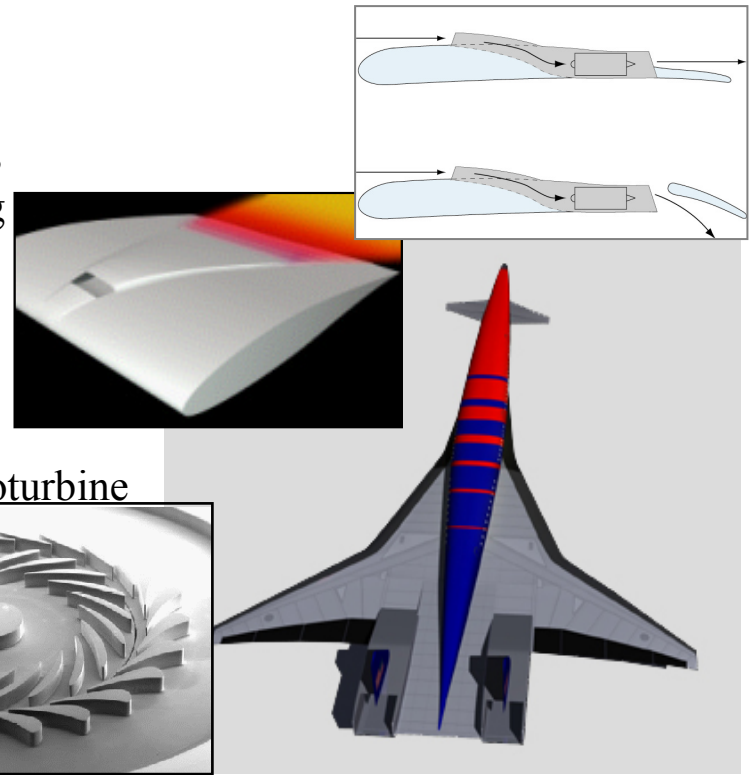
Advanced photonics



Distributed, Vectored & Innovative Propulsion Systems

Distributed Engines/ Distributed Exhaust

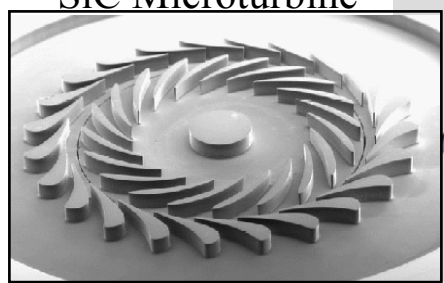
- Multiple low-cost, low power engines deployed along wing providing distributed thrust and thrust vectoring
- Aircraft boundary layer ingestion using Micro-Turbines
- High aspect-ratio nozzles embedded in the wing trailing edge using Ducted Polymer Matrix Composite nozzles
- Embedded inlets & nozzles employing flow-control

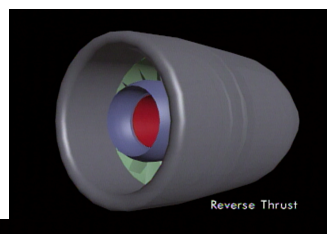


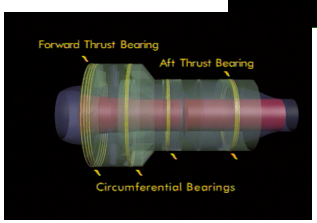
Revolutionary Propulsion Systems

- Exoskeletal Engine
- Pulse Detonation Engines/Hybrids
- Others

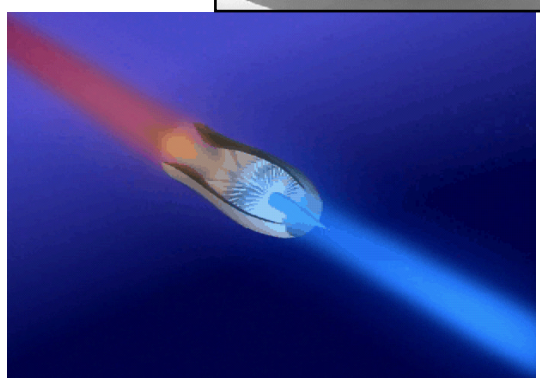
SiC Microturbine

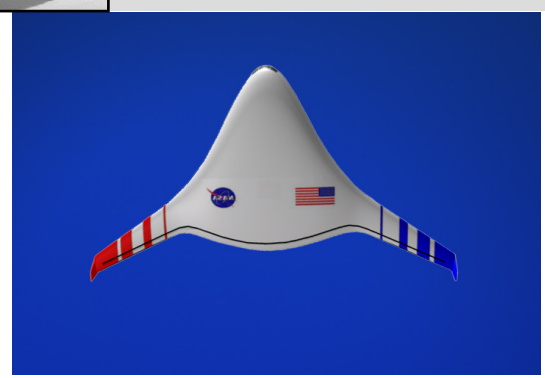






Exoskeletal

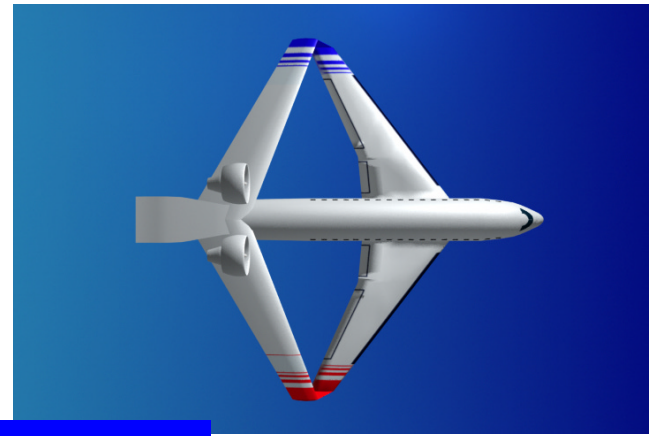


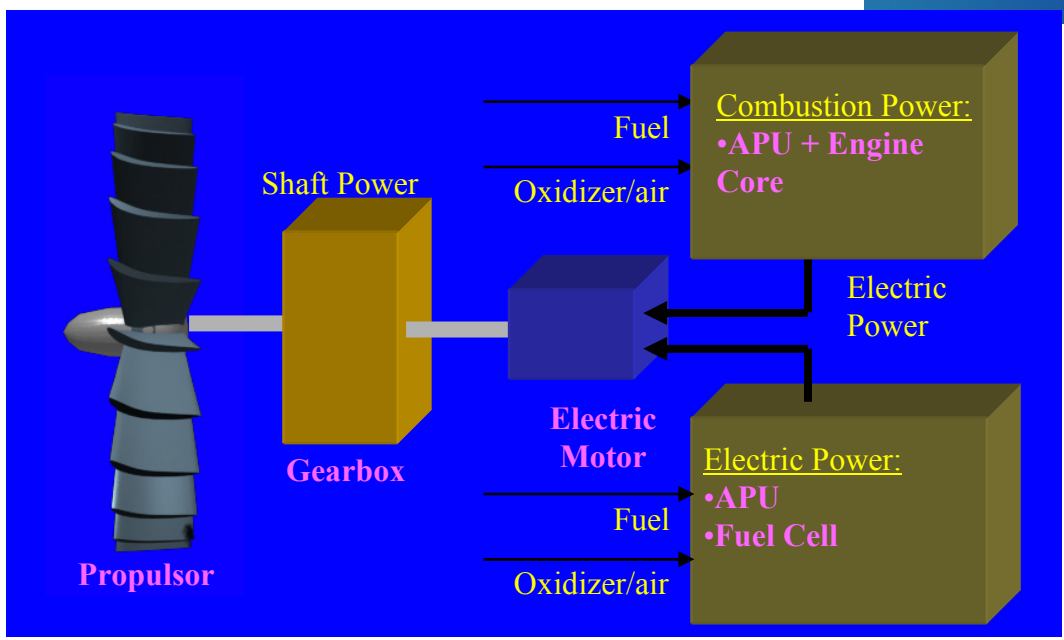


Alternative Energy Propulsion

Hybrid Combustion/Electric

- Takeoff thrust-augmenting Auxilliary Power Unit (APU)
- On-board electric power for zero emissions fan thrust





Propulsion & Power University Partnerships

Competitive Selections (FY02)

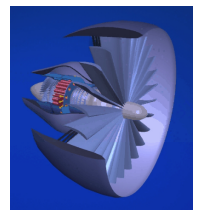
- 36 new **U-grants** = $3.6M, open competition among universities
- 9 new **U-contracts** = $0.9M, open competition among universities and small businesses ($2.0M total)
- Aeropropulsion & Power URETI **Cooperative Agreement** = $3.0M/yr for up to 5 years

Other U-Investments

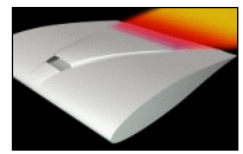
Project level grants, consortium support, faculty & student fellowships, and cooperative agreements = $6.0M

Summary

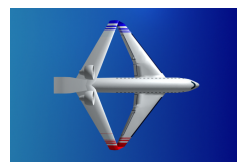
Propulsion& Power R&T will enable new engine and aircraft systems that will revolutionize aviation by providing:



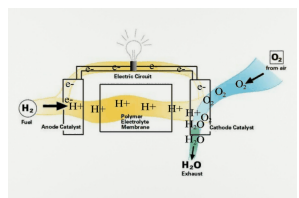
- Emerging ultra-low noise & emissions, using intelligent turbofans.



- Future distributed, vectored and/or innovative propulsion systems with 24 hour operations and greater community mobility.



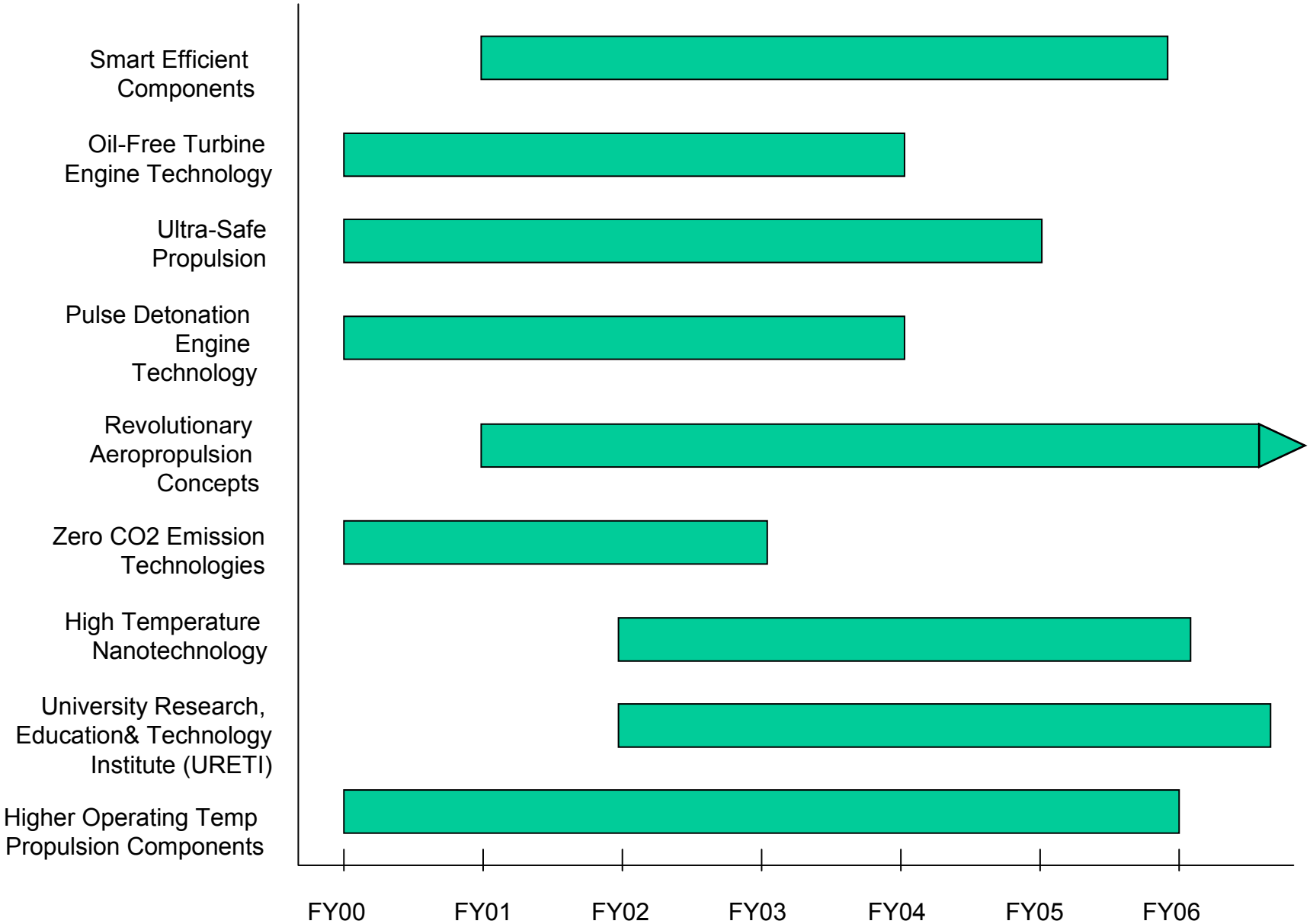
- Successful hybrid combustion/electric propulsion systems leading to near-zero emissions and silent aircraft.



- The culmination of these revolutions will deliver all-electric powered airplanes, which achieve zero-impact emissions and noise with high-capacity, on-demand operation.

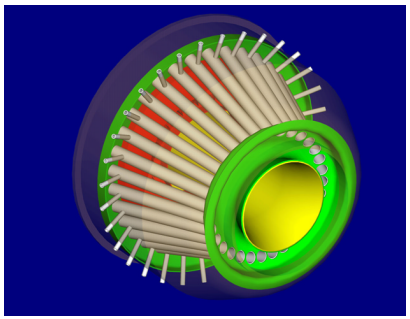
Back-up Slides

Propulsion & Power – Project Timelines



Current Efforts - New Propulsion Concepts

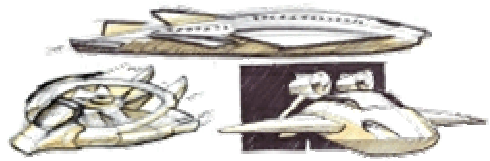
Pulse Detonation Engine Technology



Potential benefits:
- 20-30% combustor total pressure gain
- 22-26% improvement in fuel consumption

Technical challenges:
- Materials fatigue
- Acoustics
- Unsteady performance
- Energy extraction
- More

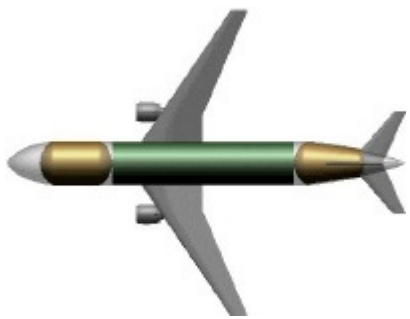
Revolutionary Aeropropulsion Concepts



Systems Analyses on Advanced Concepts
- Distributed/vectored propulsion
- Exo-skeletal
- Dual fan
- Levitated ducted fan

Next Generation Fuel Cells
Cryogenic Electric Motors

Zero CO2 Emissions Technologies

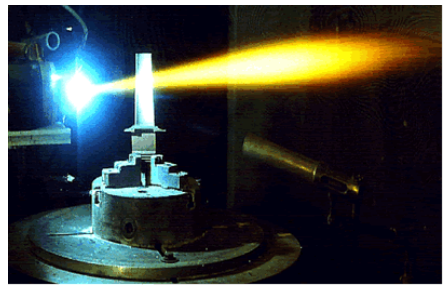


Next Generation Fuel Cells
Alternatives for electric- powered flight
Optimization of H2 fueled turbofan
NOx emissions from H2 combustion

Current Efforts – Foundation Technologies

University Research, Engineering & Technology Institute (URETI)

Georgia Institute of Technology
Case Western Reserve University
Florida A&M University
Ohio State



Higher Operating Temp Propulsion Components:

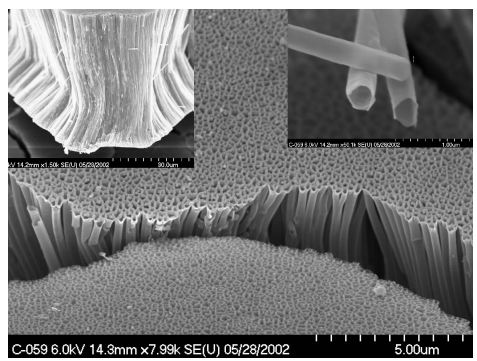
Extend temperature capability of all classes of materials throughout the entire engine.

- Develop life prediction capabilities for resulting materials and components.
- Validate material characterization behavior and component structural performance with data from rig/engine tests.

Research Areas

System level engineering analysis and technology integration methods
Enabling technologies for components and systems
Intelligent engine components and systems
High performance components
Advanced power technologies

High Temperature Nanotechnology



Focus on Silicon Carbide (SiC) for high temp application :

- high modulus
- hardness
- light weight
- oxidative stability
- chemical resistance
- H.T. semiconductor
- H.T. optical material

Current Efforts -Turbine Engine Technologies

Increase Compressor Stage Loading and Efficiency

Flow Control
Unsteady Aerodynamics/
Blade Flutter Control

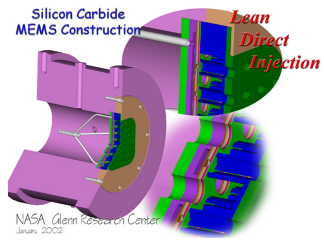
Ultra-low Emission Combustors Design/Analysis Tools

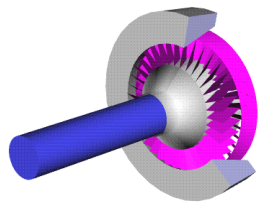
Lean Direct Injector (LDI)
National Combustor Code Development
Understanding of Combustion Instabilities

Increase Turbine Stage Loading and Efficiency

Turbine Heat Transfer Research/Modeling
Flow Control for Low Pressure Turbines
Low Pressure Turbine CFD Simulation

Light weight, high strength
fan containment

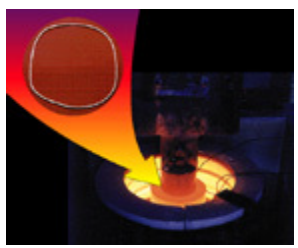




Develop Enabling Sensors for Smart/Active Control Systems

Crack resistant materials

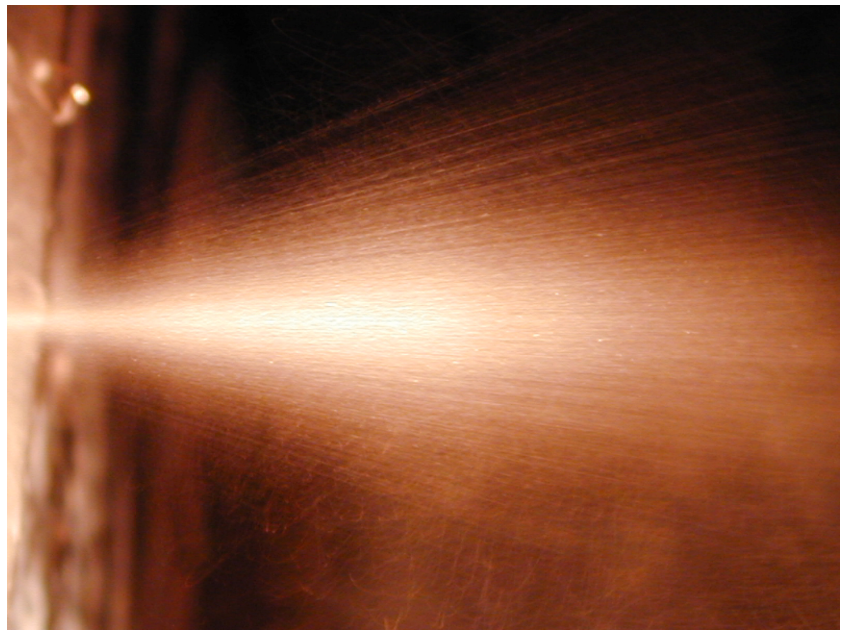
Revolutionary Acoustic Seals
Advanced Non-Contacting Seals



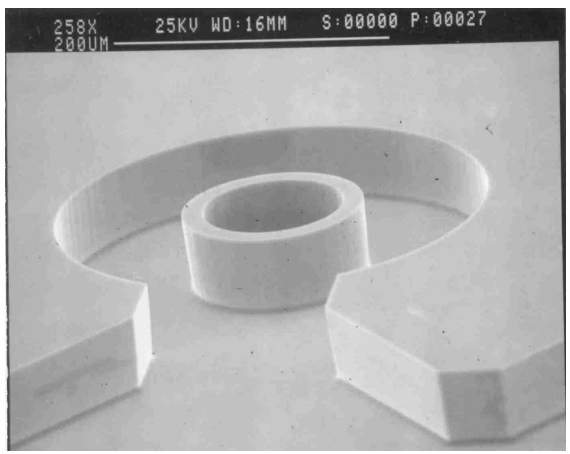
High-Temperature Magnetic Bearings
Self-tuning Vibration Absorbers
Air bearings to eliminate oil system

SEC Project - ADVANCED LEAN DIRECT INJECTOR CONCEPT

Quarter piece part of batch fabricated LDI laminate in silicon carbide



Evaluation of LDI nozzle fuel spray pattern for single fuel injector with mixing chamber



Flow channel fabricated in silicon

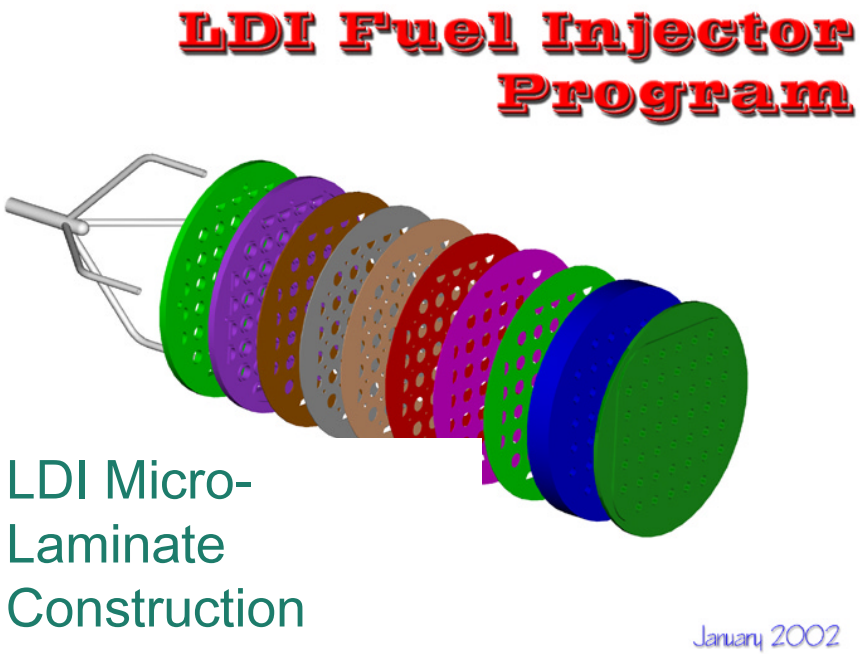
<u>Accomplishments:</u>

- ***Completed proof of concept for assembly of the SiC laminate LDI array, including deep reactive ion etching batch fabrication and multi-layer wafer bonding***
- ***Completed initial thermal and structural analysis of the LDI assembly***
- ***Conducted single injector simplex test to evaluate LDI nozzle fluid spray pattern***

SEC Project - ADVANCED LEAN DIRECT INJECTOR (LDI) CONCEPT

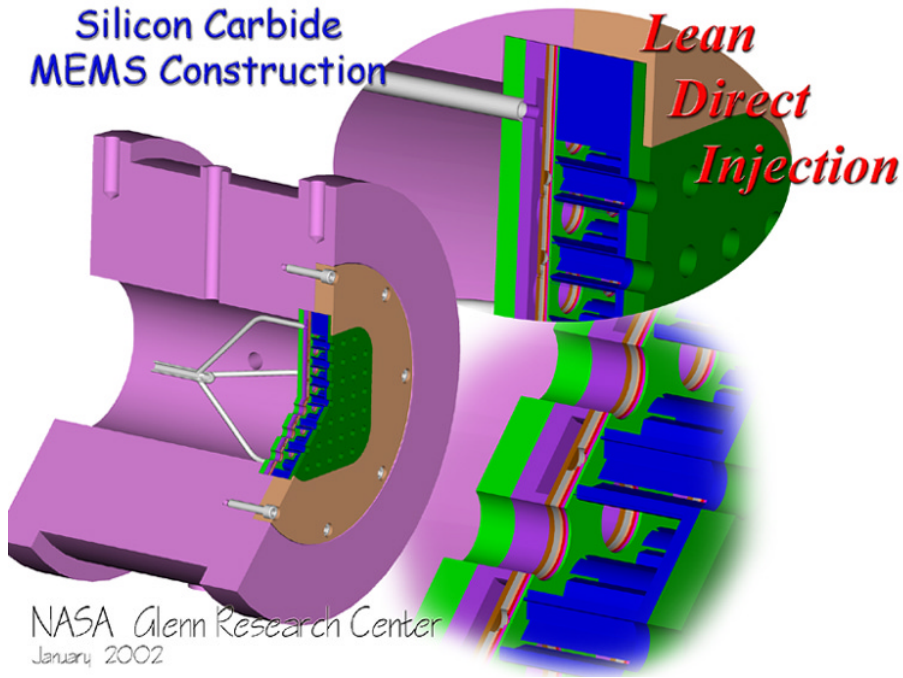
Objective :

Demonstrate revolutionary fuel injector concepts that utilize advanced technology, including metals, ceramics, and MEMS technology in flame-tube tests, to achieve the 80% NOx reduction goal, and reduce particulate and aerosol emissions.



LDI Micro-Laminate Construction

LDI Hardware installed in Flame Tube Test Chamber

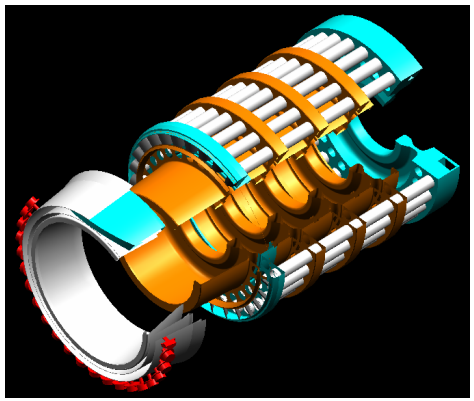


PDET Project - Hybrid Conceptual Design Study

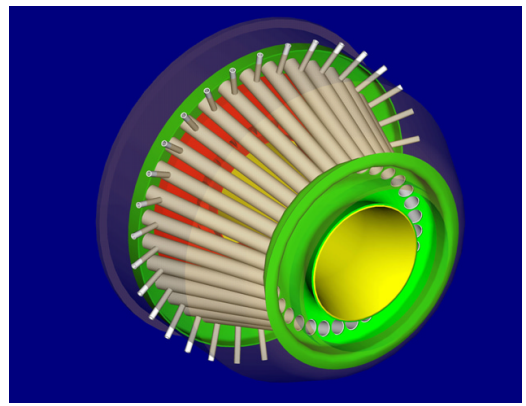
Objective: Complete assessment and conceptual design of PDE-based hybrid cycle and combined-cycle propulsion systems.

Shown: Representative combustor and engine concepts for PDE-based 50- and 300-passenger class subsonic vehicles and a Pulse Detonation Rocket Engine (PDRE) employed with a Rocket-Based Combined Cycle (RBCC) access-to-space vehicle.

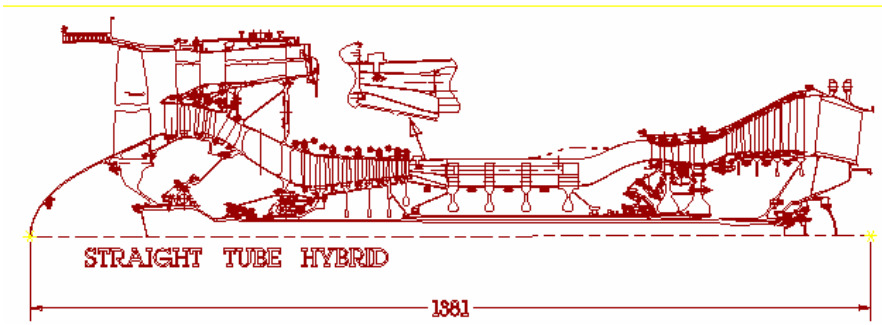
P&W PDE Combustor Concept



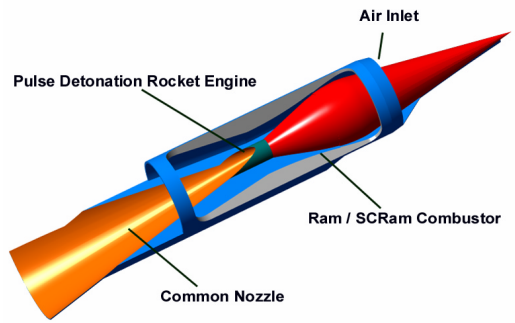
APRI PDE Combustor Concept



P&W Hybrid Engine Concept



PDRE-RBCC Engine Concept

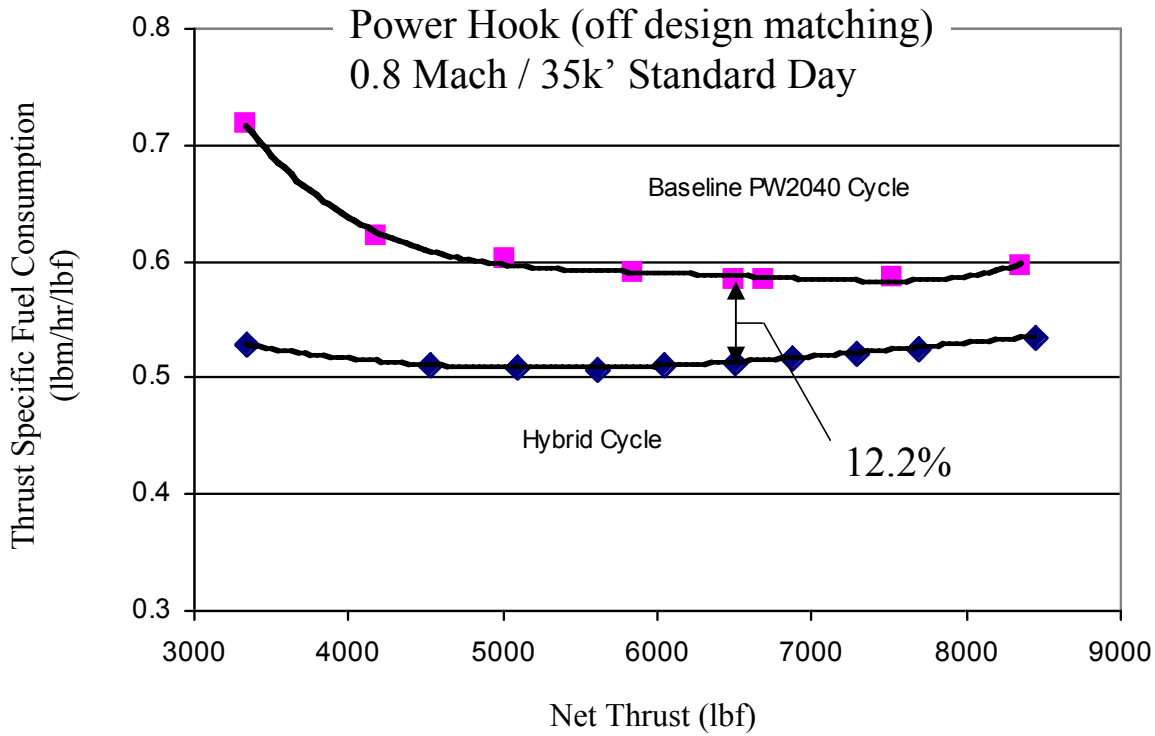


Pulse Detonation Based Combined Cycle Engine Pod

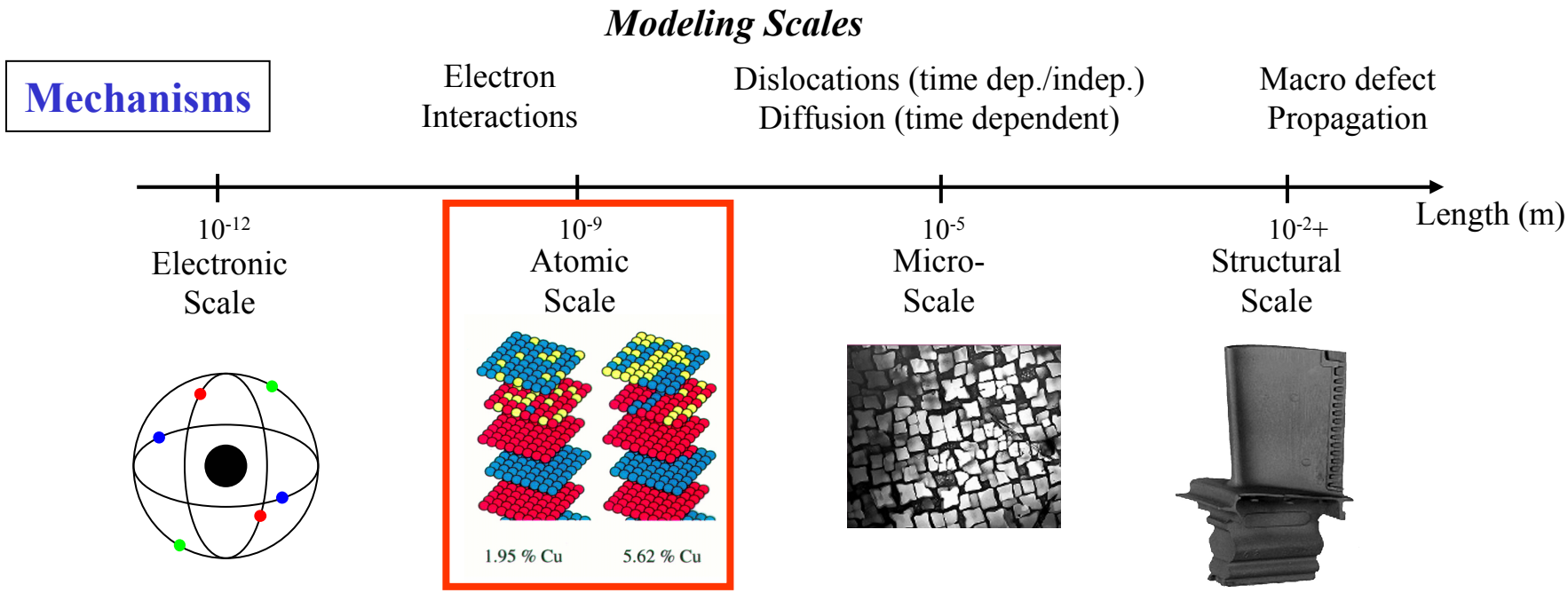
PDET Project - Pulse Detonation Engine (PDE)-Based System Conceptual Design

Results: A total of eleven design concepts were completed by the P&W, APRI and NASA study teams for hybrid (i.e., gas turbine engines) and combined-cycle propulsion systems utilizing pulse detonation (PD). First-order system performance analyses and hybrid engine component design and performance sensitivities were also completed. The hybrid engine concepts were designed to take best advantage of the potential benefits of a PD-based system. Initial assessment of the PDE concepts indicates increased performance potential.

- Fuel Economy (TSFC) at Cruise Improved 12.2%
- 6.3% lower engine weight
- 14.4% decrease in mission fuel burn



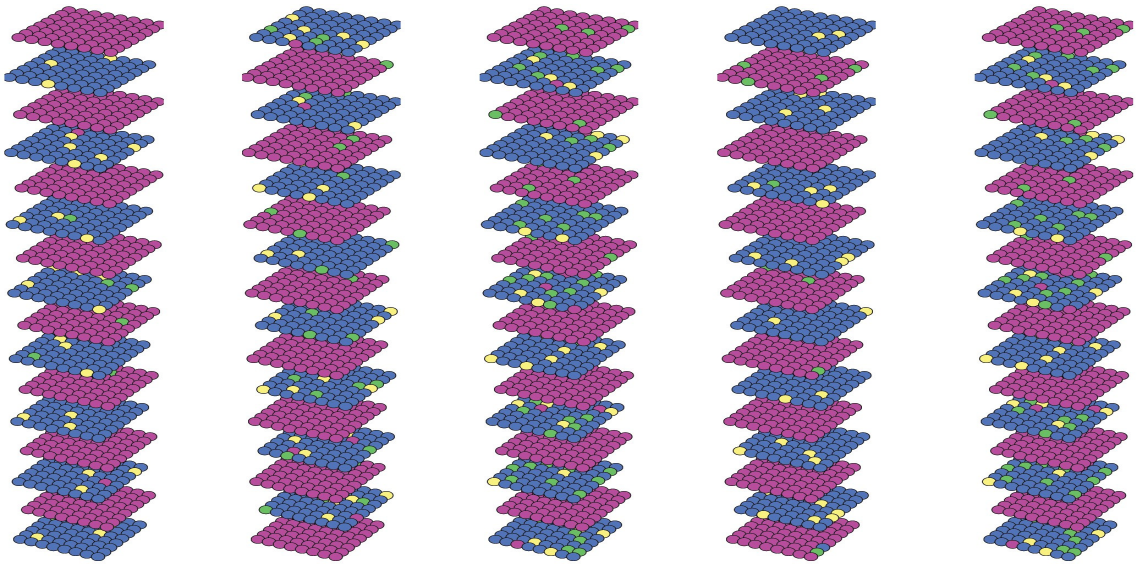
HOTPC Project - Computational Materials R&T



The Alloy Design Workbench Software Code will enable a designer/engineer to computationally create and evaluate a multitude of alloying materials, and assess the desired properties at a fraction of the cost and time that is associated with the current practices of building, testing, and analyzing.

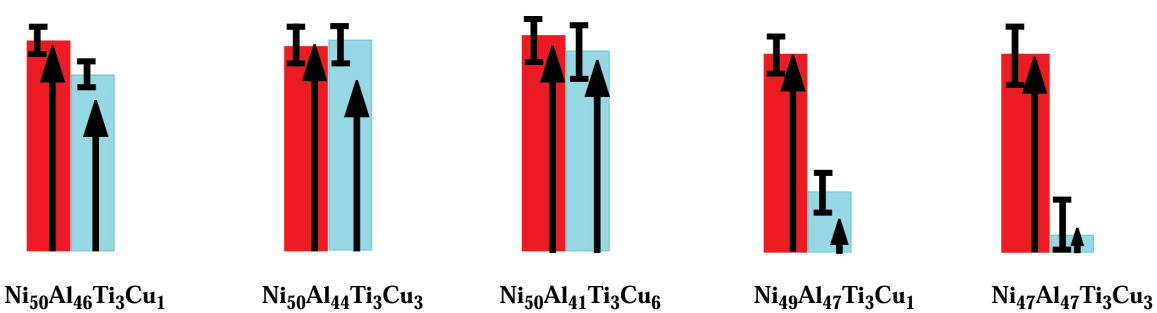
HOTPC Project - Recent Model Results

Alloy Design Workbench Utilized to Model Site Occupancy in NiAl Alloys



Ni
Al
Ti
Cu

ADW Produced Results in 2 Days



$Ni_{50}Al_{46}Ti_3Cu_1$ $Ni_{50}Al_{44}Ti_3Cu_3$ $Ni_{50}Al_{41}Ti_3Cu_6$ $Ni_{49}Al_{47}Ti_3Cu_1$ $Ni_{47}Al_{47}Ti_3Cu_3$

Experimental Data Generated in a PhD Dissertation

Validated Results Generated in a Fraction of the Time